Analysis of students' perceptions on the concepts of solar influence and atmospheric fluctuation phenomena for climate change prediction

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Abstract: **This study investigated students' understanding on the concepts of solar influence and the effects on atmospheric fluctuation phenomena for climate change prediction. This study adopted the descriptive design, 400 students were randomly selected from three tertiary institutions in Ondo West LGA, Ondo State. A validated Questionnaire (Cronbach coefficient was 0.96) were used to collect data for the study. Three research hypotheses and one research question were tested, and data were analyzed using Descriptive statistics and T-test. Having analyzed the data, the major findings reveal that students have a general perception on solar influence on climate change and that the level of atmospheric awareness of climate variability and climate change was significantly high. Also, it was observed that the incorporation of solar radiation as a topic into the school curriculum will improve student's cognitive ability. It is therefore recommended that the profile and awareness of the atmosphere through appropriate communication channels like publication of articles on climate and solar radiation should be encouraged in schools. Also, there should be availability of weather station with appropriate meteorological instrument to measure elements of climate such as rain gauge for rainfall, wind vane for measuring the direction of wind, maximum thermometer to check the highest temperature and minimum thermometer to check the minimum temperature reached in the atmosphere, barometer for measuring atmospheric pressure and so on.**

Keywords: **Climate change, Prediction, Perception, Solar, Influence and Radiation**

I. INTRODUCTION

Solar radiation powers Earth's climate system and, consequently, it is often simple-minded thought that changes in this solar output must be responsible for changes in Earth's climate. However, the huge thermal time constant of the outer part of the Sun limits the variability in its surface temperature, and hence its total power output, which is dominated by visible and infrared emissions from the solar surface (the photosphere) (Lockwood, 2004). As a result, changes in solar power output on decadal, centennial and millennial timescales are limited to small changes in effective surface temperature (associated with magnetic fields) and potential, although as yet undetected, solar radius variations (Solanki *et al.,* 2005; Lockwood, 2010).

Larger percentage variations are seen in solar Ultra Violet (UV) emissions (Lean *et al.,* 1997) which arise from the lower solar atmosphere (the chromosphere) (Loukitcheva*et al.,* 2009) and which influence the stratosphere in Earth's middle atmosphere between 10 and 50 km (Gray *et al.,* 2010). Even more variable are solar X-rays and extreme ultraviolet (EUV) emissions that originate in the upper solar atmosphere (the corona) and dominate the behavior of Earth's uppermost atmosphere (the thermosphere, above about 90km altitude) (Le *et al.*, 2011). Solar energetic particles (SEP) are emitted by solar flares and from the shock fronts that form ahead of super-sonic ejections of material from the corona (Schwenn, 2006). SEPs are incident upon Earth's atmosphere in polar region where they enhance the destruction of stratospheric ozone (Jackman *et al.,* 2006; 2008). Even more energetic are galactic cosmic rays (GCRs).

These particles are not generated by the Sun; rather, they originate at the shock fronts emanating from violent galactic events such as supernovae explosions. However, the expansion of the shielding solar magnetic field into interplanetary space results in the Sun modulating the number of GCRs reaching Earth (Potgieter, 2008). Air ions generated by GCRs enable Earth's global electric (thunderstorm) circuit (Rycroft et al. 2008), and it has been proposed that they also modulate the formation of low-altitude clouds (Svensmark and Friis-Christensen, 1997). The Sun also emits a continuous stream of low-energy charged particles called the solar wind (e.g., Marsch 2006). A small fraction of the solar wind energy incident on Earth is extracted by the geomagnetic field and deposited in the thermosphere at high latitudes (Cowley 1991; Thayer and Semeter 2004). This deposition changes the behavior of the thermosphere globally (e.g., Fuller-Rowell et al. 2007), but this is an extremely low-density atmospheric layer, and there are no robust observations, nor any confirmed theory, that suggests these thermospheric variations are transmitted through the middle atmosphere to the troposphere below.

Both electromagnetic and charged particle emissions from the Sun are known to vary over the decadal-scale solar magnetic activity cycle, as do GCR fluxes (see review by Lockwood 2004). But any effects on climate are much more significant for any variations over longer timescales. This review

discusses and evaluates potential effects on Earth's climate of variations in these solar emissions. ''Top-down'' mechanisms involve solar Ultral Violet (UV) irradiance (or perhaps energetic particles) modulating stratospheric temperatures and winds which, in turn, may influence the underlying troposphere where Earth's climate and weather reside. These contrast with ''bottom-up'' effects in which the total solar irradiance (TSI, dominated by the visible and near Infrared-IR) variations cause surface temperature changes and upward coupling to the troposphere.

Perceptions on the causes of climate change and its effects are thought to contribute to ways of finding possible solutions to the problem (Wolf and Moser, 2011; Mertz et al., 2009). Although most scientists and the general public believe climate change is taking place (Versprille et al., 2017; Yang et al., 2018), the causes and effects are contentious (Chang & Pascua, 2016; Nakayama et al., 2019; Weber, 2016; Yu et al., 2020), thus making it difficult to address the problem (Leiserowitz, 2007). There have been attempts at a global level to address climate change: first, committing to reducing emissions (Original framework of the Convention on Climate Change) and second, the introduction of legal and economic sanctions to countries which do not meet their initial target (Kyoto Protocol). Despite the foregoing, there has been little compliance (Leiserowitz, 2005).

Climate change has been defined by Weber (2010) as systematic changes in average conditions over time. These changes are difficult to observe and discern without statistical measurement, and this makes it difficult for the skeptics to believe climate change is happening (Weber, 2010). Although climate change may occur in different parts of the world, it will result in heterogeneous effects which may result in the destruction of some ecosystems (Brody et al., 2008; Leiserowitz, 2005).

Climate change is not a new phenomenon, as early as 1827 Fouries noted an increase in atmospheric carbon dioxide (CO2) levels and greenhouse gas effects (Leiserowitz, 2007). There have been many workers in this field until, notably, Calendar made a link between climate change and anthropogenic climate change in the 1930s (Hulme, 2009). Yet there are different schools of thought on what causes climate change, the most dominant being anthropogenic and natural causes. When the link between climate change and emissions was made, the fossil fuel industry in the United States of America in the late 1980s launched a public campaign to discredit science and the anthropogenic causes of climate change (Lorenzoni et al., 2007). This campaign and other causes have made it more difficult to convince some members of the public about the link between climate change and human behavior.

Investigations of students' climate change perceptions reveal important insights about their way of thinking and understanding of environmental issues and scientific concepts. Studies on climate change show that students have lack of perceptions on ozone layer depletion and global warming, on climate and weather (Lombardi and Sinatra, 2012, Gowda et al.,1997), on the radiation involve in the greenhouse effect (Choi et al., 2010), and on the causes and consequence of climate change (Pruneau et al.,2001). These lacks of perceptions persist even after receiving instruction about climate change and weather (Cordero et al.2008). Further, (Li & Liu, 2021) confirms the awareness of climate change among higher institution but expressed concerns around students' understanding of the underlying causes of the phenomenon. Submissions by (Aksit et al., 2018; Dawson, 2015; Li & Liu, 2021) suggest that the role of instruction in designing undergraduate curriculum cannot be overemphasized. It ensures students increase their climate science knowledge and also their risk perceptions as future decision makers.

Solar influence on Climate change is a critical issue that has affected all and sundry in the society such as anthropogenic etc. As such many debates, studies and projects have been conducted in a bid to make an efficacious impact in places affected by climate change. In general, this study hopes to also identify the knowledge gap between experts and laymen and attempt to bridge it by bringing climate change deliberations to the domain of the general public through informing the study participants (students).

Research Question

What is the general student's perception on solar influence on climate change in Adeyemi College of Education Ondo, Ondo state?

Research Hypotheses

The following hypothesis was generated:

1. **H_0:** level of student's perception on solar influence on climate change is not significantly high

   H_1: level of student's perception of solar influence on climate change is significantly high

2. **H_0:** there is no significant difference between male and female student on their perception on solar influence on climate change

   H_1: There is a significant difference between male and female student on their perception on solar influence on climate change

II. METHODOLOGY

Research Design

The descriptive survey design was adopted for this study.

Sampling Technique and Sample

The population of the study consisted of 150 undergraduate students selected randomly from three tertiary institutions in Ondo West Local Government Area, Ondo State. The institutions are Adeyemi College of Education, Ondo;

University of Medical Science and Wesley University, Ondo, Ondo state. A total of 150 students, which is 30% of the entire population in the local government area. Four of the faculties/schools were selected from each institution randomly to prevent clumsiness and make it manageable using random sampling techniques.

Research Instrument

For the purpose of this study, the questionnaire was prepared and administered.The questionnaire was designed in a closed form. It was divided into three parts: the introductory section, the "A" section and the "B" section. The introductory part consists of the topic of the research work and stated the aim of the study. Section A, ask for the respondent personal data and section B gave instruction on how to fill the questionnaire, it also consists of the questions to be responded to by those involved.The questionnaires were distributed to the students in the various Departments which were based on four rating scale.

Instrument Validation

The research instrument was subjected to Cronbach reliability test. The Cronbach coefficient value was 0.97. This value confirmed that the instrument was reliable in achieving the study objectives.

III. METHOD OF DATA ANALYSIS

Data obtained were later subjected to statistical analysis using Mean and Standard deviation to analyze the collected data from these institutions. A t-test was conducted to determine if there is a significant difference in perceptions by gender.

IV. RESULT AND DISCUSSION

4.1 Research Question: What is the general student's perception on solar influence on climate change in Adeyemi College of Education, Ondo?

Table 4.1: Mean Response on the general student's perception on solar influence on climate change.

S/N	Items	Mean	S.D	Remark
1.	Solar energy is produced by the action of the sun.	3.42	0.87	Agreed
2.	Study of climate helps to predict when those natural disasters are imminent.	2.89	0.90	Agreed
3.	Climate change is refers to a change of climate that is attributed directly or indirectly to human activities.	3.69	0.74	Agreed
4.	Climate change encompasses environmental issues like flooding, temperature rise, sea level rise and extreme weather condition.	3.32	0.80	Agreed

5.	Level of awareness of climate change is low among students.	3.60	0.66	Agreed
6.	Solar influence on surface climate associate with the depletion of greenhouse effects and ozone layer.	3.34	0.85	Agreed
7.	The sun is the source of most of energy that drives the biological and physical process in the world around us.	2.68	0.72	Agreed
8.	Direction of the wind is one of the factors that affecting the climate change.	3.54	0.94	Agreed
9.	Students have always been educated on the issues of climate.	3.76	0.51	Agreed
10.	The better our knowledge about the state of the atmosphere, the better our knowledge on climate change.	3.76	o.65	Agreed
11.	The rate of the energy coming from the sun changes slightly day to day.	3.75	0.69	Agreed
12.	Most worlds' climate scientists agree that human activities are the main reason behind climate change.	3.52	0.90	Agreed
13.	Introduction to climate courses in school helps in the understanding of climate change.	3.88	0.43	Agreed
14.	Our skin creates vitamin D naturally when exposed to solar radiation.	3.91	0.47	Agreed
15.	Exposing bottled water to sunlight for six hours or more can kill many harmful pathogens.	3.71	0.47	Agreed
16.	Change in solar output might affect our climate directly by changing the rate of solar heating of the earth and the atmosphere.	3.09	1.17	Agreed
17.	Inaccurate knowledge about climate change affects human activities.	3.81	0.59	Agreed
18.	Incorporation of solar radiation as a topic into the school curriculum will improve student's knowledge on how it influences climate change.	3.97	0.29	Agreed
19.	The study of Solar influence on climate change will help to identify the knowledge	3.86	0.44	Agreed

	gap between an expert and the layman.			
20.	Very large amount of CO_2 are also released by burning of fossil fuel.	3.81	0.61	Agreed

Level of awareness and conceptual understanding of climate change

In 4.1 above, the first 10 question items shows the mean spread examining the level of awareness, interests and conceptual understanding of students concerning the subject of climate change. The mean score (3.42) in item 1 was greater than 2.50 of mean, this implies that respondent agreed with solar energy is produced by the action of the sun. Item 2 the mean score (2.89) was greater than 2.50 of mean, this implies that respondents agreed with the study of climate helps to predict when those natural disasters are imminent. Item 3 the mean score (3.69) was greater than 2.50 of mean, this implies that respondents agreed with climate change attributed directly or indirectly to human activities. Item 4 the mean score (3.32) is greater than 2.50 of mean, this implies that the respondents agreed with climate change encompasses environmental issues like flooding, temperature rise, sea level rise and extreme weather condition. Item 5 the mean score (3.60) was greater than 2.50 mean of mean, this implies that respondents agreed with the level of awareness of climate change is low among student. Item 6 the mean score (3.34) is greater 2.50 of mean, this implies that respondents agreed with solar influences on surface climate associate with the depletion of greenhouse effects and ozone layer. Item 7 the mean score (2.68) is greater than 2.50 of mean, this implies that respondents agreed with sun is the source of most of energy that drives the biological and physical process in the world around us. Item 8, the mean score (3.54) was greater than 2.50 of mean, this implies that respondents agreed with direction of wind is one of the factors that affect the climate change. Item 9, the mean score (3.76) was greater than 2.50 of mean, this implies that respondents agreed with Students have always been educated on the issues of climate. Item 10, the mean score (3.76) was greater than 2.50 of mean, this implies that respondent agreed that the better our knowledge about the state of the atmosphere, the better our knowledge on climate change.

In summary, the findings show a positive response, that is, an acceptable level of awareness and interest in climate change among students, through sufficient understanding of the definition of terms and basic concepts. Thus, a positive perception is accepted on the perceptions of climate change, atmospheric phenomenon and other variability.

Perceptions of impacts, solar influence and other factors contributing to climate change

In the second batch of the 10 question items of Table 4.1, we observe the extent of understanding, among students, of the impacts from human activities, impacts and influence of solar fluctuations and other factors in the atmosphere contributing to climate change.

Specifically, in item 11, the mean score (3.75) was greater than 2.50 of mean, this implies that respondents agreed with the rate of the energy coming from the sun changes slightly day to day. Item 12, the mean score (3.52) was greater than 2.50 of mean, this implies that respondents agreed with most worlds' climate scientists agree that human activities are the main reason behind climate change. Item 13, the mean score(3.88) was greater than 2.50 of mean, this implies that respondents agreed with introduction to climate courses in school helps in the understanding of climate change. Item 14, the mean score (3.91) was greater than 2.50 of mean, this implies that the respondents agreed with our skin creates vitamin D naturally when exposed to solar radiation.

Also, Item 15 the mean score (3.71) was greater than 2.50 of mean, this implies that the respondents agreed with exposing bottled water to sunlight for six hours or more can kill many harmful pathogens. Item 16, the mean score (3.09) was greater than 2.50 of mean, this implies that the respondents agreed with change in solar output might affect our climate directly by changing the rate of solar heating of the earth and the atmosphere. Item 17, the mean score (3.81) was greater than 2.50 of mean, this implies that the respondents agreed with inaccurate knowledge about climate change affects human activities. Item 18, the mean score (3.97) was greater than 2.50 of mean, this implies that the respondents agreed with incorporation of solar radiation as a topic into the school curriculum will improve student's knowledge on how it influences climate change. Item 19, the mean score (3.86) was greater than 2.50 of mean, this implies that the respondents agreed with the study of Solar influence on climate change will help to identify the knowledge gap between an expert and the layman. Item 20, the mean score (3.81) was greater than 2.50 of mean, this implies that the respondents agreed with very large amount of CO_2 are also released by burning of fossil fuel.

Again, these results, though mixed, reveals an acceptable understanding of the deeper issues of impacts from solar influence, human activities and atmospheric fluctuations on climate change phenomenon. This shows that students' climate change content knowledge have been appreciably enhanced by receiving instruction on these concepts including sufficient exposure to the risks of climate change in practice.

4.2. T-test analysis of male and the female student on the perception of solar influence on climate change

	N	Mean	S.D	Std. error mean	DF	T-cal (t-test)	T-table (p-value)	Remark
Male	75	3.4300	0.87514	0.02767				
					148	3.94	1.96	Significant
Female	75	2.8900	0.90483	0.02861				

From table 4.2, the t-test (t-calculated value) of 3.94 was greater than the p-value (T-table) of 1.96 at 5% level of significance ($\alpha=0.05$). Therefore, null hypothesis was rejected while alternative hypothesis was accepted. This implies that there was a significant difference between male and female students on their perception on solar influence on climate change. Comparing this result with the mean result for each group, we also find a significant difference. The mean score of male was (3.43) was higher than that of female (2.89). Hence, male student have overall better understanding of the impacts of atmospheric fluctuations and solar influence on climate change.

V. DISCUSSION OF FINDINGS

Based on the result of the above finding, table 4.1. shows that the level of student's perception of solar influence on climate change is significant high and so within acceptable range. This is based on the opinion of the respondents who agreed that solar energy is produced by the action of the sun, the study of climate helps to predict when those natural disaster are imminent, climate change attribute directly or indirectly to human activities, climate change encompasses issues like flooding, temperature rise etc solar influence on surface climate associate with the depletion of green house effect of ozone layer. This was in line with Leiserowitz (2007) who noted an increase in atmospheric carbondixiodes (CO_2) levels and green house gas effect.

Table 4.2 shows that there was a significant difference between male and female student on their perfection on solar influence on climatic change based on the collected data. The male student have better understanding on exposing bottle water to sunlight for six hours or more can kill harmful pathogens. Sun is the source of most of energy that drive the biological and physical process in the world around us, direction of wind is one of the factors that affect the climate change rate of energy coming from the sun changes slightly day to day, most worlds' climate scientists agreed that human activities are the main reason behind climate change, our skin create vitamin D naturally when exposed to the solar radiation.

This was in line with IPCC (2007) who noted that the impacts of gender differences on agriculture, ecosystem add biodiversity is attributed to the rising concentration of green house gasses and increasing environmental degradation.

VI. CONCLUSION

On the basis of a critical observation made on the available data for this study, it was seen that students have a general understanding of solar influence on climate change and that incorporation of solar radiation as a topic into the school curriculum will improve student's cognitive ability. The understanding of the conceptual definitions, impacts and factors affecting climate change has more positive than negative implications for students in Adeyemi College of education Ondo, Ondo state.

As learning is a consistent and continuous process, it is advisable that students endeavour to regularly gather additional knowledge about solar radiation and climate, then there will be vivid and deeper understanding of solar influence on climate change. The impact of climate change in our activities of life cannot be over emphasized because of the great merits. In the light of the above analysis, the researcher has indicated that students have a general understanding of solar influence on climate change and the positive effects over human activities. In order for the students to have more knowledge on solar influence on climate change, the researcher is therefore suggesting that the following points should be considered;

1. Incorporation of solar radiation as a topic into the school curriculum to improve student's knowledge on how it influences climate change.
2. There should be availability of weather stations with appropriate meteorological instrument to measure elements of climate. Such as rain gauge for rainfall, wind vane for measuring the direction of wind, maximum thermometer to check the highest temperature and minimum thermometer to check the minimum temperature reached in the atmosphere, and barometer for measuring atmospheric pressure.
3. The better our knowledge about the state of the atmosphere, the better our knowledge on climate change. Hence, introduction to climate courses in school helps in the understanding of climate change.
4. Within the school environments, every opportunity should be used to raise the profile and awareness of the atmosphere, variability of its elements and factors impacting climate change through appropriate communication channels.

REFERENCES

[1]. Agho, K., Stevens, G., Taylor, M., Barr, M. and Raphael, B. (2010). 'Population risk perceptions of global warming in Australia.' *Journal of EnvironmentalResearch.* 1(110):756-763.

[2]. Akasofu, S. I. (2009). *'Two natural Components of the Recent Climate Change.'*Http://www.people.iarc.vaf.edu/Sakasafu (Accessed on 11/10/2013). (Accessed 6/09/2014).

[3]. Aksit, O., McNeal, K. S., Gold, A. U., Libarkin, J. C., & Harris, S. (2018). The influence of instruction, prior knowledge, and values on climate change risk perception among undergraduates. *Journal of Research in Science Teaching*, *55*(4), 550–572.

[4]. Aldahan A, Hedfors J, Possnert G, Kulan A, Berggren A-M, So¨derstro¨m C (2008) Atmospheric impact on beryllium isotopes as solar activity proxy. Geophys Res Lett 35:L21812. doi:10.1029/2008GL035189

[5]. Apata, T.G., Samuel.K.D. and Adeola, A.O. (2009).Analysis of climate change perception among arable food crop farmers in south-west Nigeria. Conference paper presented at International Association of Agricultural Economists 2009, Beijing. China.

[6]. Boykoff M. and Boykoff J. (2007). Climate change and journalistic norms:A case-study of US mass-media coverage Geoforum2007; 38:1190-1204. DOI:10.1016/j.geoforum.2007.01.008

[7]. Brody,S.D., Zahran,S., Vedlitz,A., &Grover,H. (2008). Examining the relationship between physical vunerability and public perceptions of global climate change in the United States. *Environment and behaviour* 1(40):72-95

[8]. Brown,C.,Leene,E.,Putman,D.,&Whited,B. (2012).Comparing survey results to assess climate change/Global warming awareness, perceptions and beliefs of college students in the United States and China. Wisconsin. University of Wisconsin-Eau Claire. 82

[9]. Baldwin MP, Dunkerton TJ (2001) Stratospheric harbingers of anomalous weather regimes. Science294:581–584. doi:10.1126/science.1063315

[10]. Baliunas S, Jastrow R (1990) Evidence for long-term brightness changes of solar-type stars. Nature348:520–523. doi:10.1038/348520a0

[11]. Barnard L, Lockwood M., Hapgood M. A,, Owens M.J, Davis C.J, Steinhilber F (2011) *Predicting space Climatechange*.Geophys Res Lett 38:L16103. doi:10.1029/2011GL048489

[12]. Barriopedro D., Garcia-Herrera R., and Huth R (2008) Solar Modulation of Northern Hemisphere winter blocking.*Journal of Geographical Research*113:D14118. doi:10.1029/2008JD009789

[13]. Beer J (2006) Solar variability and climate change. *Solar Variability Earth Climatic* 76:751–754

[14]. Benestad RE, Schmidt GA (2009) Solar trends and global warming. *JournalGeophys Research* 114:D14101. doi:10.1029/2008JD011639

[15]. Berrisford P, Hoskins BJ, Tyrlis E (2007) Blocking and Rossby wave-breaking on the dynamical tropopause in the Southern Hemisphere. *Journal Atmospheric Science* 64:2881–2898. doi:10.1175/JAS3984.1

[16]. Blaauw M., Heuvelink G.B.M, Mauquoy D., Van der Plicht J., Van Geel B. (2003), A numerical approach to 14Cwiggle-match dating of organic deposits: best fits and confidence intervals. QuatSci Rev 22:1485–1500. doi:10.1016/S0277-3791(03)00086-6

[17]. Broccoli AJ et al (2003) Twentieth-century temperature and precipitation trends in ensemble climatesimulations including natural and anthropogenic forcing. *JournalGeophys Research* 108(D24):4798. doi:10.1029/2003JD003812

[18]. Brohan P., Kennedy J.J, Haris I., Tett SFB, Jones, P.D (2006), Uncertainty estimates in regional and globalobserved temperature changes: a new dataset from 1850. *Journal Geographical Research* 111:D12106. doi:10.1029/2005JD006548

[19]. Bro¨nnimann S, Ewen T, Griesser T, Jenne R (2007) Multidecadal signal of solar variability in the upper troposphere during the 20th century. *Space Science Review* 125:305–315. doi:10.1007/s11214-006-9065-2

[20]. Brown, B.H (2008) Short-term changes in global cloud cover and in cosmic radiation. Jou*rnal of Atmospheric Solution -TerrPhys*

[21]. Chang, C.-H., & Pascua, L. (2016). Singapore students' misconceptions of climate change. *International Research in Geographical and Environmental Education*, *25*(1), 84–96.

[22]. Dawson, V. (2015). Western Australian high school students' understandings about the socioscientific issue of climate change. *International Journal of Science Education*, *37*(7), 1024–1043.

[23]. Li, Y.-Y., & Liu, S.-C. (2021). Examining Taiwanese students' views on climate change and the teaching of climate change in the context of higher education. *Research in Science & Technological Education*, 1–14.

[24]. Nakayama, M., Taafaki, I., Uakeia, T., Seru, J., McKay, Y., & Lajar, H. (2019). Influence of religion, culture and education on perception of climate change, and its implications. *Journal of Disaster Research*, *14*(9), 1297–1302.

[25]. Versprille, A., Zabih, A., Holme, T. A., McKenzie, L., Mahaffy, P., Martin, B., & Towns, M. (2017). Assessing student knowledge of chemistry and climate science concepts associated with climate change: Resources to inform teaching and learning. *Journal of Chemical Education*, *94*(4), 407–417.

[26]. Weber, E. U. (2016). What shapes perceptions of climate change? New research since 2010. *Wiley Interdisciplinary Reviews: Climate Change*, *7*(1), 125–134.

[27]. Yang, L., Liao, W., Liu, C., Zhang, N., Zhong, S., & Huang, C. (2018). Associations between knowledge of the causes and perceived impacts of climate change: A cross-sectional survey of medical, public health and nursing students in universities in China. *International Journal of Environmental Research and Public Health*, *15*(12), 2650.

[28]. Yu, T.-K., Lavallee, J. P., Di Giusto, B., Chang, I.-C., & Yu, T.-Y. (2020). Risk perception and response toward climate change for higher education students in Taiwan. *Environmental Science and Pollution Research*, *27*(20), 24749–24759.